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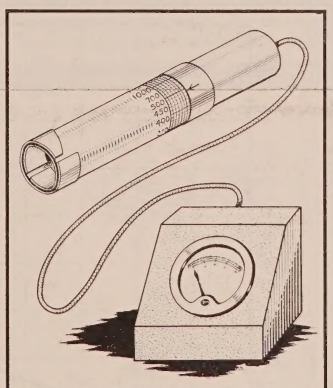
UHF Instrumentation

Part 1. A UHF Absorption Frequency Meter

By the Engineering Department, Aerovox Corporation

THE coming-of-age of the ultra-high frequency portion of the radio spectrum, brought about by the recent freeze-lifting on UHF television permits and the activation of the Citizens Radio Service, brings with it many problems in UHF instrumentation. Although the industry has foreseen the expansion into this region for a considerable period of time, simple test equipment for use at these frequencies has been noticeably lacking. For this reason, the TV technician, experimenter, and radio amateur working at frequencies between 300 and 1000 megacycles per second may find himself in the position of having to construct much of his own test equipment. Special techniques will be required since this range is the clumsy "transition region" between the more familiar VHF practices and the "plumbing-and-hardware" techniques of the microwaves. This issue of the RESEARCH WORKER, as well as several which will follow from time to time under this series, is intended to provide a useful service to its readers in this respect by describing simple basic equipment which will be needed for servicing UHF television and performing experimental work at the lower UHF range.

The experimental UHF absorption meter described here can be constructed without special tools and represents the most simple device available for determining the frequency of UHF signal sources. It appears as shown in Fig. 1.



UHF FREQUENCY METER

FIG. 1

Anyone who has used an absorption meter at low frequencies is familiar with the utility of such a device for rough frequency determination. As used for low frequency applications, it usually consists of a parallel L-C circuit capable of tuning over a wide range and calibrated in terms of resonant frequency or wavelength. It is used to determine the unknown frequency of a signal source by loosely coupling it to the output of the signal source and noting the effect on the latter as the frequency meter is tuned to the unknown frequency. This effect may be either an increase in the plate current or a decrease in the grid current of the source oscillator as the frequency meter is tuned to resonance. This interaction is caused by the increased loading effect produced by the energy absorption of the resonant circuit. The absorption meter may also be made self-indicating by coupling an indicator, such as a small incandescent bulb or a crystal rectifier-meter

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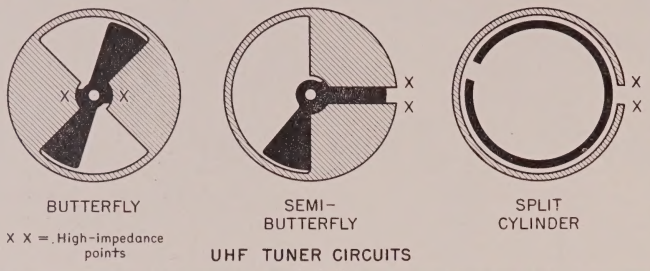


FIG. 2

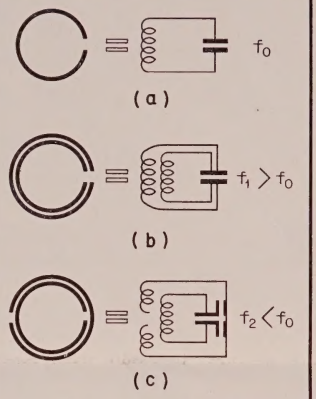


FIG. 3

combination, to it. An absorption meter is usually used for rough frequency "search" work.

UHF Design Considerations

For use in the presently expanding portion of the UHF spectrum, an absorption frequency meter should have the following characteristics:

(a) Tune from about 300 to at least 1000 megacycles.

(b) Self-indicating for use with non-metered local oscillators, etc.

(c) Compact form factor to permit use in restricted space.

(d) Rugged construction for good frequency stability.

(e) High "Q" for sharp resonance indication.

For our present purpose the frequency meter should also be easy to construct and calibrate.

A survey of the types of tuned circuits available for UHF use indicates that several, such as the butterfly, the semi-butterfly, and the split-cylinder tuners, which are illustrated in Fig. 2, fulfill most of these requirements. In the form described in this issue, the split cylinder tuner has the added advantage of being the most easily constructed. For this reason it was chosen as the basis for our present design.

The split cylinder tuner, attributed to Karplus[1], is one of the types of UHF resonant circuit which is proving popular for use in UHF television converters. It consists of two cylinderical metal tubes mounted concentrically so that one is free to rotate within the other. Both tubes are split lengthwise and have diameters such that the spacing between them is only a few thousandths of an inch. The manner in which wide range tuning is accomplished with this combination is shown in Fig. 3. The equivalence of one of the split cylinders to a conventional L-C resonant circuit is illustrated in Fig. 3a. The gap corresponds to the capacitance while the solid portion opposite it is equivalent to a one-turn inductance. In 3b the effect of placing a similar ring close around the first, with the gap in the same position, is shown. In this position, the resonant frequency of the combination is maximum, since the inductances of the two rings are essentially in parallel, while the total capacitance is not appreciably changed. When the outside ring is rotated 180 degrees, as in Fig. 3c, the effective capacitance of the resonant circuit is greatly increased by the presence of the inner ring across the gap of the outer one, which has the effect of a split-stator condenser. The inductance of the tuned circuit is also maximum in this position, since the split portion of the inner cylinder adjacent to the inductive portion of the outer one has little effect. Thus, the resonant frequency of the combination is at a minimum when the rings are in this position. Therefore an appreciable tuning range is covered by 180-degree rotation of the movable cylinder. For simple split-cylinders, however, the tuning is not linear with rotation, but becomes very rapid at the high frequency end of the range where the movable cylinder first crosses the gap of the fixed one.

Construction

As usually employed for UHF television, the split cylinder tuner is constructed with the outer cylinder fixed in a housing and the inner ring is free to rotate within it on a tuning shaft supported on bearings mounted in the ends of the housing. The close spacing between the two must be maintained accurately, requiring considerable precision machine work.

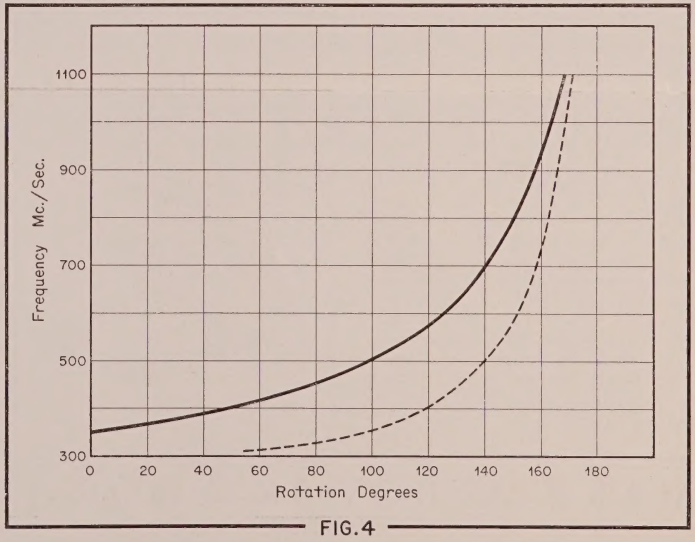


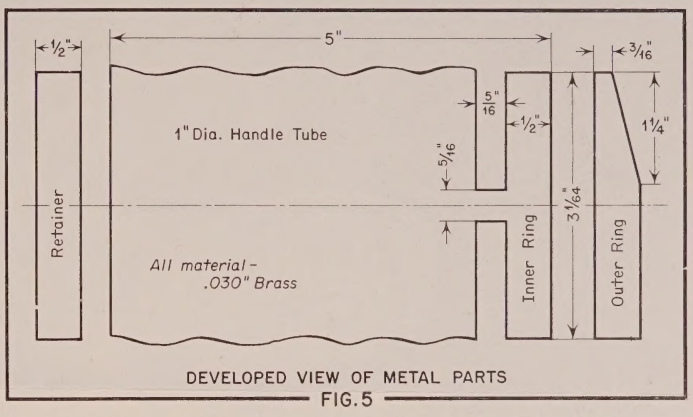
FIG. 4

The construction of the absorption frequency meter described here is a modified version of this tuner, suggested by Kumpfer. In this form it is easier to construct and has a form factor well adapted to this application, as shown in Fig. 1. It is made by providing the tuner with a handle consisting of an extension of the inner split cylinder and attached to it only by a narrow section of the brass tube from which both are made. The outer ring is separated from the inner one by a dielectric tube which fits snugly over the inner ring and tubular handle and acts to space the two split cylinders. Tuning is then accomplished by rotating the dielectric tube around the metal tube. Means are provided to assure axial alignment of the two split cylinders and a graduated scale is marked on the dielectric tube for calibration of the frequency meter. The tuning range is about 350 to 1100 megacycles. To avoid the rapid variations of frequency with rotation at the high end, the outer cylinder has been shaped so that the variation of the capacitance across the gap of the inner ring is not so rapid as is the case when the tuning ring is left full width. The resulting tuning curve is shown in solid lines in Fig. 4, while the uncorrected curve is shown in dotted lines. By further shaping of both cylinders, the tuning could probably be made essentially linear, but at some sacrifice in total coverage.

The dimensions of the frequency meter parts are shown in Fig. 5 which represents the metal tubular parts spread flat. The body of the frequency meter and the inside cylinder are made from a single piece of standard brass tubing 1 inch in diameter with a .030-inch wall. The overall length of the brass tube is 5 inches. The inside resonanting ring is ½-inch wide and is separated from the rest of the handle tube by a 5/16-inch gap except where it is joined to it by a portion of the brass wall 5/16-inch wide diametrically opposite the slot, which is ⅛-inch wide. These cuts in the brass tube can be made with a hack-saw, after which the edges are dressed smooth with a file.

A retaining collar of brass sheet stock or tubing is sweated around the end of the handle tube opposite the split ring to provide a stop for the dielectric tube. This collar may be scribed with an indexing mark for calibration of the frequency meter.

The outside tuning ring may be made from a piece of .030-inch flat brass stock bent into a split tube with a ⅛-inch gap, or it may be fabricated from a slightly larger size of tubing and formed to fit well around the inner ring after splitting. The dimensions of this ring, after shaping for better tuning characteristics, are given in Fig. 5.

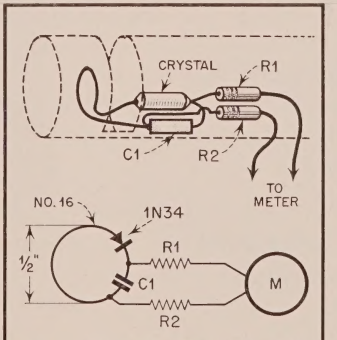


DEVELOPED VIEW OF METAL PARTS

FIG. 5

The dielectric tube which spaces the two split cylinders is fabricated by winding two layers of thin wax-paper around the handle tube, extending from the edge of the retaining collar to the end of the split cylinder. This tube is cemented at the seams with *Duco* cement so that it will turn smoothly on the brass tube. A layer of white bond paper is then cemented over the wax paper and the outside tuning ring is fastened to the tube thus formed so that its position coincides with the inner ring when the edge of the dielectric tube is held against the retaining collar. A piece of graph paper is cemented to the dielectric tube up to the retaining collar to provide a calibration scale.

The frequency meter can be used in this form to determine the frequency of circuits which have metered plate or grid circuits, or ones where a meter can be conveniently inserted. For non-metered circuits, however, the frequency meter can be made self-indicating with little additional effort by mounting a coupling loop and crystal detector circuit within the handle so that it samples the magnetic field within the resonator. The rectified current, which increases abruptly when the frequency meter is tuned to resonance, is indicated by a meter connected to leads brought out through the handle. The circuit of this indicator, as well as a sketch of the physical arrangement, is shown in Fig. 6. Any meter with a full-scale reading of one milliampere or less will be suitable. If a microammeter is used, less coupling is required between the frequency meter and the circuit being measured, resulting in better accuracy.



R1, R2 - 1000 OHMS (AEROVOX Type 1097)
C1 - 25 MMFD., (AEROVOX Type 1468)
CRYSTAL - 1N34

METER INDICATOR DETAILS

FIG. 6

Calibration

The absorption meter must be calibrated against a standard such as a calibrated UHF signal generator or a variable-frequency UHF oscillator in turn calibrated by means of an accurate *Lecher wire* system. Details of the use of such a system were discussed in the AEROVOX RESEARCH WORKER for August, 1950. Enough points should be taken to allow marking a frequency scale on the graph paper attached to the paper tube. After the scale is calibrated, the exposed portion of the paper tube is covered by a smooth layer of transparent cellulose tape to protect it and prevent moisture absorption.

References

(1) E. Karplus, Wide Range Tuned Circuits and Oscillators for High Frequencies, Proc. I.R.E., July, 1945.

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